University of California, Davis
Department of Agricultural Economics

Technical Completion Report

Effect of Changing Water Quality and Supply on Imperial Valley, California

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Research Objectives

The overall research objectives of this project were to investigate the short- and long-term impact of increased salinity and reduced water supply in the lower Colorado River on the economy of the Imperial Valley of California. Originally suggested as a three year project to the California Water Resource Center, the research was conducted in annual phases over a four-year period funded in part by the Matching Fund program of the Office of Water Resources Research, PL 88-379, as ammended, in part by cooperative research funds from the U.S. Department of Agriculture, and in part by the Department of Agricultural Economics, University of California, Davis.

Specific research objectives for this project required that the work be conducted in several topical phases. These were, the Imperial Valley irrigated agriculture phase, the Salton Sea-Imperial Valley recreation phase, an institutional-legal phase, and an upper watershed hydrology modeling phase.

One or more of the following served as specific sub-objectives of each phase:

1. To identify and establish physical and economic characteristics of irrigation water resources in order to evaluate costs, quality, technological, and uncertainty components in production adjustments of farmers in Imperial Valley, California.

2. To develop a production response surface for crops using irrigation water with yield as the dependent variable and quantity and quality of water as two independent variables.

3. To estimate both short- and long-run demand schedules for irrigation water in this area.

4. To develop a computer simulation model to analyze alternative water quality management policies which take into account the private costs to the individual firm as well as the public social costs of water quality degradation due to increased mineral and chemical concentrations and residues in agricultural waste waters.

5. To determine the value of the marginal product for irrigation water and the changes in this value due to marginal decrements of different components of the water quality.

6. To analyze the effect of incremental changes in the quality and quantity of inflows to the Salton Sea on the water based recreation benefits from this body of water.

7. To describe and analyze the legal and institutional setting with respect to the management of water quality and quantity in the Imperial Valley, California, with special reference to the state and federal water quality standards, including U.S. obligations to Mexico on the Lower Colorado River.

8. To develop a detailed computer hydro-salinity simulation model taking into account knowledge of precipitation; elevation; stream flow; and plant, soil, and moisture relations in order to predict upper basin salinity loads in relation to natural and managed land use situations and effect of irrigation water quality on plant growth and yield.

9. To determine optimum irrigation management practices and drainage investments under conditions of high evaporation and low water quality.

Research Results

All water, flowing in river systems, contains some dissolved salt -- usually identified as a basic salt load. A portion of the water deverted from rivers and streams at higher elevations returns to the streambed with the basic salt load more highly concentrated -- by evaporation -- along with an additional salt load picked up as the water moves through the soil. As water flows from the head of the stream to its mouth, this process is repeated causing salinity to be greatest at lower reaches. Even water not diverted by man will increase in salt load as it flows around, over, and through soil or rocks, dissolving minerals as it flows in surface channels or through subsurface aquifers.

Effects on Agriculture of Water Quantity and Quality

Agriculture, in the Imperial Valley is strongly affected by variation in irrigation water salinity and in turn causes a significant effect on other water users in the basin. Predicting future effects of changes in the quality and flow of the river stresses the dynamics involved in solutions of the

problem. The magnitude and seriousness of the problem increases with the length of the stream and the aridity of the region.

Predictive studies receive increasing emphasis not only because competition for resources increases among the various needs of the burgeoning population but because computer technology is available for attempts to probe the future. The Imperial Valley irrigated agriculture phase investigated how agricultural production might be affected by changes in the quantity and quality of irrigation water.

The area under consideration in an early test was the Imperial Valley. A program model was developed consisting of 21 prototype farms to simulate the valley's production pattern. The study shows that water quality in the future will significantly affect agricultural production in the Imperial Valley. The results of this first study may, of course, be modified by changes in water-management technology, greater understanding of plant growth, and other fruits of research.

Crop yields are a function of water quantity and water quality besides other factors such as weeds, crop varieties and fertilizers. Water quantity (supply) usually has a positive effect, with greater amounts increasing yields. Water of lower quality (greater salt content) usually reduces yields, but the poor quality can often be offset by using greater quantities in a trade-off between quality and quantity. Most studies ignore the quality dimension and the trade-off possibilities, so they may support conclusions that result in suboptimal levels of water use and a misallocation of other production resources.

The Imperial Valley is a typical arid area with rare and scant rainfall and limited groundwater resources, agriculture and related activities there depend completely on irrigation water diverted from the Lower Colorado River. Water, therefore, is a matter of concern as to its quantity and quality available in the future. The modelings made of the production of major crops of the area as affected by changes in water quality are used to identify effects on farm income within the framework of multiple crop selection and combination. As the salinity level of 1970 (1,500 micromhos of electrical conductivity) increases to a predicted level of 2,000 micromhos in the year 2000, net returns from the model farms are shown to decrease by 12-15 percent and the projected marginal return to water decreases from $4.40 to $4.00 per acre-foot.

Assume that water costs to the Imperial Irrigation District remain at $2.35 per acre-foot and that other farm production costs remain at the present level. The District's current water entitlement of 2.55 million acre-feet can be used profitably up to a salinity of 4,200 micromhoms but not beyond. At 5,700 micromhos the District demand for water would be reduced from the current 2.5 million acre-feet to 1.0 million acre-feet. With salinity of 1,500 micromhos the breakeven demand for water quantity would be higher, or approximately 3 to 3.5 million acre-feet in farm headgate delivery per year. Under the high salinity conditions, only the best soils will remain in production. Larger farms may have a higher return to water and therefore may survive better than smaller farms when water quality is at an economically critical state, although it was found that a uniform allocation of water among farms increased the average income of small farms.

Regional effects of irrigation water can be aggregated on the basis of two regional models:

1) A model allocating equal shares of water on a per acre basis, with each farm unit making decisions independently, considers micro-effects at the farm level and then sums them to develop macro-effects at the regional level.

2) The regional planning model attempts to maximize regional income as a whole by considering as a whole the allocation of limiting factors such as irrigation water, crop allotments, and market shares.

From empirical results, the regional model has a higher economic efficiency in terms of regional income, whereas the equal-share model gives a more equal income distribution among the various farms and subregions. The tradeoff between the planning model and the equal share model is a loss of $1.8 million in regional farm income or about 2 percent of the total with a greatly reduced variance of that income. Since efficiency and a more equal income distribution are both socially desirable, considering one method superior to the other is difficult. The final reconciliation -- and policy decision-making -- must come from the public through institutional processes such as legislative action, irrigation district action and court action.

The study demonstrates a method of formulating a production function and demand schedule for water considering both quantity and quality. The empirical results may assist decision-making on use and allocation and development of irrigation water even though modifications may be expected as knowledge and technology improve.

Salinity in Recreational Water Uses

Even fish and wildlife and the sportsman who pursues them are affected by the way salinity is managed in the river basin. The Salton Sea of California serves as the outfall for Imperial Valley drainage water and is a case in point where the cumulative salinity has endangered the sport fishery and adversely affected private and public recreation investments in an area heavily dependent on recreation and tourism.

Projecting recreational uses of natural and manmade areas has traditionally been done on a simple basis of extrapolation from past use figures. Very few attempts have been made to analyze how recreational use figures will be affected by changes in the quality of recreational experiences in an area. Such an evaluation seemed particularly needed for the Salton Sea.

That body of water, about 75 miles southeast of Los Angeles, is a natural sump with no outlet to the sea. It was created in 1905-1907 when the Colorado River breached a canal gate and the entire flow collected in the basin. The sea has since been maintained by natural runoff and irrigation return flows. After being stocked by the California Department of Fish and Game, it developed into an excellent sports fishery, with an estimated 1.5 million recreation industry. Its increasing salinity is now at levels that seriously threaten its survival.

A simulation model developed for the area was used in projecting recreational use of the Salton Sea as a function of a large number of complex variables. The approach is considered to have promise in the field of recreation planning where hard data are scarce and extremely expensive to procure. The feedback and sensitivity capabilities of systems analysis can provide recreation planners with an economical alternative to current inadequate or overly expensive procedures. Planners should have a new confidence in the approach since it incorporates subjective elements that characterize recreationists and investors in recreation facilities.

Legal Aspects of Salinity

The waters of the Colorado River present an institutional and legal complex for management of water by the seven irparian states of the United States and for the Republic of Mexico. Those waters have been allocated primarily by various agreements: an international treaty, two interstate compacts, a congressional interstate apportionment, and, infrequently, by litigation. Analysis of the basic characteristics of resolving water quantity conflicts several as a point of departure for the institutional-legal phase of this project concerned with resolving water quality conflicts.

Maximizing the social and economic benefits of this great resource has had important consequences: 1) virtually complete control of the river; 2) increasing use and reuse for manifold purposes; 3) progressive deterioration of the water quality from that intensive use; and 4) a passing to downstream users of the economic costs engendered by pollution resulting from beneficial upstream use.

Solving the basinwide salinity problem is impeded by legal and institutional constraints on division and use of the water — constraints that are the product of an international treaty, a Supreme Court decision, federal law, interstate compacts, Indian water rights, and state water laws.

Further complicating matters is the original overestimation of the river supply, leading to overallocations to the various interested political entities.

The lower Colorado has always had waters naturally more saline than most major rivers, estimated at 600 parts per million at the site of the Imperial Dam. About 75 percent of the salts load in the Lower Basin is from the Upper Basin. That 75 percent was estimated in 1963-66 to be 58 percent from natural sources and 42 percent from irrigation. Nearly three-fourths of salinity increases projected for 1970-2000 are expected to be from development in the Upper Basin.

Water consumed (by plant transpiration, evaporation, etc.) and therefore not returned to the river is presently less than the amounts allocated to the upper and lower basins for consumptive use. Studies indicate, however, that development in the Upper Basin by the year 2000 will deplete the river so that the water remaining cannot meet the provisions of the compact of 1922 and the Mexican water treaty.

The overall situation, despite attempts at remedy through physical adjustment of various kinds, guided correctly or not by research findings, nevertheless leads to extended pondering of the legal situations as anticipated from established laws and possible legislation and agreements in the future. Each of many aspects of the situation has given rise to a number of opinions.

As to the rights and remedies of California and the landowners in the Imperial Valley, the following points appear to have validity:

1) It is doubtful that California, as a Lower Basin state, has a right to water of any specific quality under the provisions of the Colorado River Compact of 1922.

2) There is a bare possibility that California as parens patriae could obtain adequate relief under the Supreme Court's original jurisdiction through application of a federal common law nuisance. Such a suit would be a class action against Colorado, Wyoming, and Utah and seven irrigation districts in said states as representatives of other irrigation districts similarly situated.

3) The Federal Water Pollution control Act Amendments of 1972 may lead to the establishment of numerical criteria for salinity throughout the Colorado River system. This could effectively protect California users of Colorado River water from further salinity increases. However, the enforceable sections of the 1972 Act do not regulate agricultural runoff or return flows, a major contributor to the salinity problem.

4) It is possible that the substantive and procedural effects of the National Environmental Policy Act and section 309 of the Clean Air Act on the federal decision-making process may result in a modification or withdrawal of some of the more than 50 Upper Basin water development projects currently proposed, authorized, or under construction. Slowing Upper Basin water-development projects would very likely reduce projected salinity increases.

5) It is possible that an indirect effect of a recent federal district court holding — certain to be appealed — that the Colorado River Storage Project Act forbids the intrusion of waters from Lake Powell into the Rainbow Bridge National Monument will be a reduction in planned Upper Basin water projects, which in turn could reduce projected salinity increases.

6) It is unlikely that California Civil Code section 3479 or the common law of California would give rise to a tort action in private nuisance asserting that use of their water and land by Imperial Valley landowners has been interfered with by drainage programs in the Upper Basin that have introduced saline irrigation return flows into the Colorado River system and thereby degraded such waters to the substantial injury of Imperial Valley users.

7) It is doubtful that a class action brought before a court sitting in California would hold Colorado, Wyoming, Utah, and irrigation and drainage districts within the said states responsible for substantial damage resulting from pollution caused by their saline irrigation return flows and drainage water.

Similar points have been made with respect to the rights and remedies of the Republic of Mexico and the landowners in the Mexicali Valley.

In any case, it is apparent that a new era is at hand as regards legal problems and water. The historic focus on quantity with little or no regard for quality had been superseded by discussions that center on quality, with frequent reference to pollution, salinity, clean-air acts, and similar expressions of the complexity and unity of the various problems extending over immense areas.

Simulating a Stream-Aquifer System

Although technical and measurement difficulties loom large, major problems in modeling the complexities of salinity sources and water flows in an area are being unraveled. The upper watershed hydrology modeling phase relates natural and managed land use to salinity and water quality.

A clearer picture of the problems emerges from a model of salinity contributions in the Roaring Fork River, a major tributary of the Colorado River. The basin is fairly typical of the high alpine areas of the headwaters region of the Colorado, with land use primarily livestock and hay farming.

The model study provided two specifics of immediate value to management of the study area: 1) that salt loading from irrigation was closer to the previous low estimate of 1.27 tons per acre per year than to the high estimate of 3.0 tons; and 2) that the potentials of reducing the agricultural salt loading are great since irrigation efficiency is estimated at only 14 percent.

Groundwaters (held in aquifers) and surface waters are interrelated in a stream-aquifer system in which groundwater in the floodplain alluvium is in hydraulic connection with the stream. Maximum beneficial use of the total available water resource in a stream-aquifer system comes only through conjunctive use of the ground and surface water. Optimizing that use, however, is possible only if interrelations between the ground and surface waters are understood to the point that responses to stresses can be predicted. Successful management of the system thus depends largely on knowledge of the resource and the ability to predict both the hydrologic and chemical effects of a complex set of dynamic stresses. The need is clear for an accurate hydrologic and water-quality simulation model of the stream-aquifer system.

Publications

Several publications have already been issued under this project and others are in various stages of review. Published or completed:

1. Moore, Charles V. and J. Herbert Snyder, "Alternative Water Policies for an Arid Region," Water and Western Destiny: From Conflict to Cooperation. Proceedings of the Third Western Interstate Water Conference, Fort Collins, 1969, pp. 63-67.

2. Moore, Charles V., "Economics of Water Quality Control," Proceedings of the 39th Western Agricultural Economics Association Meetings, Tucson, Arizona, July 25-27, 1971, pp. 288-294.

3. Sun, Peter, An Economic Analysis of the Effects of Quantity and Quality of Irrigation Water on Agricultural Production in Imperial Valley, California, Ph.D. Thesis: Agricultural Economics, University of California, Davis, December 1971.

4. Moore, Charles V., "On the Necessary and Sufficient Conditions for Long-Run Irrigated Agriculture," Water Resource Bulletin, Vol. 8, No. 4, August 1972, pp. 802-812.

5. Moore, C. V., Snyder, J. H., and Sun, P., "Welfare Considerations in Resource Allocation," Paper presented, Annual Meetings of American Farm Economic Association, August 1973.

6. Howitt, R. E., Moore, S. S., Moore C. V., and Snyder, J. H., "A Simulation Approach to Recreation Planning -- A Case of Changing Quality," Accepted for publication in Annals of the Western Regional Science Association, (Vol. VIII, 1974).

7. Moore, C. V., Snyder J. H., and Sun, P., "Effects of Colorado River Quality and Supply on Irrigated Agriculture," Accepted for publication in Water Resource Research, 1974.

8. English, M. J., "The Roaring Fork Basin Salinity Model," M.S. Thesis: College of Engineering, University of California, Davis. December 1973.

Manuscripts in preparation.

1. Moore, C. V. and Snyder, J. H., "Management of Saline Water," to be submitted as a Water Resources Center Contribution Report.

2. Snyder, J. H., Moore, C. V., and Chrisman, J. C., "A Review of Legal Implications for Downstream Uses of Salinity Management on the Colorado River," to be submitted to the Natural Resources Journal.

Application of Research Results

Agencies who have indicated a keen interest in the progress of this research or who have made preliminary use of tentative findings include the California Department of Water Resources, Department of Fish and Game, and Department of Parks and Recreation. The Imperial Irrigation District expects to use results from the irrigated agriculture phase in evaluating its management policy and programs. Researchers at Colorado State University are using preliminary results in developing their investigations of management possibilities on the Colorado river. Other strong expressions of interest have been received from the State of California Colorado River Board and the Water Resources Control Board.

Student Training and Benefits

Financial support for students in three different colleges of the University of California, Davis, has been provided by this project. Both undergraduate and graduate students have had an excellent opportunity to interact and work together in a multi-desciplinary research project requiring a synthesis of both methodology and knowledge in the several fields of agricultural economics, engineering and law, specifically, the project supported research leading to a Ph.D. in Agricultural Economics, an M.S. in Agricultural Economics, a Ph.D. in Engineering, and an M.S. in Engineering. Additionally, support was provided for students working on B.S. degree programs in Agricultural Economics and a J.D. in law. A total of nine students have received some support and training from the project.